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THE EFFECT OF CARBURETOR THROTTLE SETTINGS ON THE VELOCITY DISTRIBUTION AT THE OUTLET OF A VANED AND A VANELESS SUPERCHARGER INLET ELBOW

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THE EFFECT OF CARBURETOR THROTTLE SETTINGS ON THE VELOCITY DISTRIBUTION AT THE OUTLET OF A VANED AND A VANELESS SUPERCHARGER INLET ELBOW

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SUMMARY

A study has been made to determine the effect of a carburetor and an inlet elbow on the flow at the supercharger impeller inlet. Tests were conducted on a commercial vaned supercharger inlet-elbow assembly to determine the effect on the velocity distribution at the elbow outlet by varying the carburetor throttle setting from full open to 55° closed. The tests were repeated with the vanes removed to determine their effect on the distortions produced by the carburetor throttle. Tests were also made to compare the static-pressure drop through the vaned and the vaneless elbows.

The carburetor throttle setting had a pronounced effect on the velocity distribution at the supercharger inlet. Because of the tendency of the vanes to retain the distortion created by the throttle, and because of the large wakes produced by the vanes, the velocity profile at the outlet of the vaneless elbow was decidedly more uniform than that of the vaned elbow at all throttle settings. The static-pressure drop through the carburetor and the vaneless elbow was approximately 5 percent less than that through the carburetor and the vaned elbow. The use of vanes in an elbow immediately downstream from a carburetor has an adverse effect on the velocity distribution at the supercharger inlet.

INTRODUCTION

An intensive investigation of the distribution of fuel and charge air among the cylinders is one phase of the program to improve the power, the economy, and the cooling characteristics of radial engines. Nonuniform distribution of fuel and charge air is a known cause of the spread among the cylinder-head temperatures. A considerably greater pressure drop is required for cooling when nonuniform

fuel distribution exists because the engine cooling requirements are determined by the hottest cylinder. Nonuniform distribution also produces an adverse effect on fuel economy because the entire engine must be run with rich mixtures in order to keep the temperature of the hottest cylinder within operating limits.

When fuel is injected upstream from the impeller, it is carried through the impeller by entrainment in the air stream; therefore, distortions in the velocity profile at the supercharger inlet will probably affect the fuel distribution. The throttle position has a pronounced effect on the fuel distribution in radial engines when the fuel is injected upstream from the impeller. This cause of nonuniform fuel distribution can be remedied by means of cylinder injection or by other methods of fuel injection that do not depend on the air stream for carrying the fuel through the impeller.

Even when a uniform fuel distribution exists, a spread in cylinder temperatures results from differences in the power developed by the various cylinders. This variation may be caused by an unequal air distribution among the cylinders. A general investigation is being conducted at the NACA Cleveland laboratory to determine the causes of unequal air distribution among the cylinders of a radial engine; there are many contributing factors but the relative importance of each has not yet been determined. It seemed necessary, therefore, to isolate each of the factors and to study its characteristics as fully as possible.

The first components in the engine induction system that may cause a poor velocity distribution at the supercharger inlet are the carburetor and the supercharger inlet elbow. Inasmuch as the impeller blades and the diffuser vanes act to prevent any mixing and resultant equalization of flow, an unequal air flow to the cylinders may result. The degree of this inequality of flow depends on the intensity of the distortion of the velocity profile at the supercharger inlet. Tests were therefore made to determine the magnitude and the nature of the distortion produced by a commercial carburetor and elbow and to determine the effect of changes in the throttle settings on the flow characteristics.

These tests, the results of which are presented herein, were conducted on a commercial vaned supercharger inlet elbow incorporating three turning vanes. The tests were repeated with the vanes removed to determine their effect on the flow through the elbow. The pressure drops through the vaned and the vaneless elbow were also determined.

APPARATUS

The flow tests were made on the duct-component test rig described in reference 1 and shown in figure 1. Inlet air was supplied at a static pressure of 30 inches of water above atmospheric pressure and was exhausted through an outlet to the atmosphere. The weight flow of air was controlled by use of a butterfly valve approximately 40 diameters upstream from the test section. A 16-mesh screen was inserted 20 diameters downstream from this valve to remove any flow disturbance produced by it. For the determination of the weight flow of air, a calibrated pitot-static tube and a thermocouple were installed at a reference station 20 diameters downstream from the screen. The method of calibrating the pitot-static tube and a description of the instrumentation are given in reference 1.

An assembly consisting of a commercial carburetor and supercharger inlet elbow incorporating three turning vanes was first tested. The elbow was then modified by the removal of the vanes and their supporting ribs. Figure 2 is a photograph of the carburetor-elbow installation showing the method of setting the throttle position. As shown in figure 1, an impeller-shaft housing extends across the elbow passage to the impeller face. In order to eliminate a sharp change in the section at the end of this housing, which would not exist in the actual engine installation, a wooden shaft was used as a continuation of the housing to approximately 14 inches downstream from the elbow outlet.

A boss was provided at station 2 for a survey to determine the velocity profile of the flow entering the carburetor. Four surveys were taken at the elbow outlet (station 3) at a position corresponding to the impeller inlet. Surveys A and D were 2 inches from the elbow center line and surveys B and C were 1/2 inch from the elbow center line in planes parallel to the plane of the bend. In order to accommodate the survey tube in surveys B and C (station 3), slots were cut in the shaft extending downstream from the tube. The tube could then be passed from one side of the shaft to the other by rotating it 180°.

Four bosses were also mounted at station 4, 6 inches downstream from station 3, for use in a supplementary test to obtain static-pressure surveys for comparing the static-pressure drop through the carburetor-elbow assembly with and without vanes.

TESTS AND CALCULATIONS

Two similar series of tests were made on the carburetor and elbow assembly, with and without the elbow vanes, during the investigation of the effect of throttle setting on the velocity distribution at the supercharger inlet. During these tests, surveys were taken at four locations across the outlet of the elbow in a plane corresponding to the impeller entrance. One survey was taken at a time to keep restrictions to the flow at a minimum. At each point in a traverse, the values of the static and the dynamic pressures indicated by the reference tube and the survey tube, the barometric pressure, and the temperatures at the reference and the survey stations were recorded. After each set of readings, the survey tube was reset to the next point and the next set of readings was taken until a complete survey had been made.

In order to obtain comparable results, the static pressure at the reference station was maintained at 30 inches of water above atmospheric pressure in both series. When the throttle setting was varied, the weight flow and the Mach number were changed. In order to determine the effect of the change in Mach number on the velocity profile, several check runs were made at a constant throttle setting varying the Mach number by means of the upstream throttle. In these runs the Mach number had very little effect on the velocity profile. A velocity survey was made at the inlet to the carburetor at full-open throttle to determine the velocity profile of the flow entering the test section.

The first series of tests was run on a standard vaned elbow and carburetor at carburetor throttle settings of wide open, and 15°, 30°, 45°, and 55° closed. No surveys were taken for any throttle position beyond 55° closed because the flow became so small that reliable data could not be obtained. For the second series of tests, the three vanes and the supporting ribs were removed from the elbow, and surveys were taken at the same throttle settings.

A supplemental investigation was made to compare the static-pressure drop through the carburetor and the vaned elbow with that through the carburetor and the vaneless elbow. Surveys were taken at station 4 rather than at station 3 in order to incorporate losses resulting from the equalization of the static and the velocity gradients at the elbow outlet, which should be charged to the elbow.

Air densities and velocities were calculated from standard thermodynamic relations. In order to eliminate the effect of small temporal variations in the weight flow, the velocity at each point

of a survey was corrected by multiplying it by the ratio of the average velocity at the reference station to the reference velocity at that particular point.

RESULTS AND DISCUSSION

The results of these tests are presented as nondimensional plots of V/V_{av} against l/L where V/V_{av} is the ratio of the velocity at a given point along the traverse to the computed average velocity at the survey station and l/L is the ratio of the distance of that point from the inside wall of the duct to the total length of traverse of that survey.

The velocity distribution obtained with full-open throttle at the entrance to the carburetor is shown in figure 3. The flow entering the carburetor and elbow assembly was uniform except that the boundary layer at the inside of the bend was slightly thicker than that at the outside.

The velocity distribution at the outlet of the vaned elbow (fig. 4) indicates that the principal result of closing the throttle is to greatly increase the relative velocity near the inside of the bend and to decrease it slightly near the center and the outside. Even at wide-open throttle the velocity profile at the inside of the elbow outlet is higher than that at the outside. This phenomenon is characteristic because of the pressure gradient required to turn the flow around bends. The increase in the relative velocity near the inside of the bend as the throttle was closed, however, was due entirely to the action of the throttle. This result could be expected because, when the throttle is closing, the trailing edge moves toward the inside of the bend and produces a convergent passage, causing a high-velocity jet along the inside of the bend. Conversely, the flow along the outside surface passes through a divergent section beneath the throttle, with a consequent decrease in velocity. The net effect is thus to increase the relative velocity at the inside of the bend and decrease it at the outside.

Although the velocity profile at the outside decreased as the throttle was closed to an angle between 30° and 45°, beyond this point the profile became higher until at 55° it was higher than that obtained at wide-open throttle. No definite explanation has been found for this phenomenon because the flow is greatly disturbed by the venturis, the throttle, the fixtures of the carburetor, the vanes, the vane supports in the elbow, and a secondary flow. This comparatively high velocity at the outside of the elbow at the high throttle angles

is apparently the result of an angularity in the flow induced by a combination of these disturbing factors. The profiles near the inside of the bend in surveys B and C at station 3 (figs. 4(b) and (c)) changed with the throttle angle and a dip appeared as the throttle was closed beyond approximately 25°. The appearance of this dip was probably due to a wake created by the throttle. Separation at high throttle angles was noted along the surface of the shaft nearest the inside of the elbow in surveys B and C at station 3. Examination of the elbow revealed that this flow separation was probably caused by a mass of metal supporting the inside vane at the surface of the shaft.

A prominent characteristic of the velocity profiles obtained at the outlet of the elbow was the dip located behind each vane; the location of these dips indicated that they were caused by wakes set up by the vanes. Unpublished results of investigations on the use of turning vanes in elbows have shown that, when the flow at the inlet is uniform, the magnitude of the wakes produced by vanes may be reduced to a negligible amount by the proper angular setting of the vanes; however, this setting of the vanes was found to be very critical. The carburetor throttle setting upstream from the elbow affected the angle of attack of the flow on the vanes and thus complicated the use of vanes in the supercharger inlet elbow. Though the wakes might be reduced to a minimum at one throttle setting by the proper setting of the vanes, other throttle settings would cause the formation of large wakes.

Another requirement for the proper functioning of turning vanes is a uniform velocity distribution at the inlet to the vanes. The effect of vanes on fluid flow is essentially the maintenance of the same velocity distribution downstream from the vanes that exists at the entrance to the vanes. If the velocity distribution immediately upstream from the vanes is distorted, this distortion will be retained by the vanes and will be present at the outlet. The vanes prevent the mixing of the flow and thus remove the means by which velocity distortions may be equalized. When a distorted flow exists upstream from the vanes, the effect of the vanes may consequently be exactly opposite to that desired.

In the tests to determine the magnitude of flow distortion at the elbow outlet caused by the vanes, the relative velocity near the inside of the bend of the vaneless elbow (fig. 5) increased only in the range from wide-open throttle to approximately 35° closed, in contrast to the continuous trend noted with the vaned elbow (fig. 4). Beyond 35° closed the velocity decreased until at a throttle angle of 55°, it was only slightly greater than that at wide-open throttle. This reversal in trend is similar to that found

in flow tests of a supercharger inlet elbow reported in reference 1, in which this phenomenon is explained as the result of an increase in turbulence at the high throttle angle. Closing the throttle increased the relative velocity at the inside of the bend over that at the outside. At the same time, however, the increasingly rapid expansion under the leading edge of the throttle caused separation and consequent large-scale turbulence. After the throttle had been sufficiently closed, this turbulence apparently became great enough to increase the mixing of the flow, thereby causing a partial equalization of velocity across the elbow passage. Equalization did not occur in the vaned elbow because of the action of the vanes in preventing mixing. These results, of course, apply only to installations where the carburetor has a single butterfly-type throttle in which the throttle closes when the downstream edge moves toward the inside of the bend of the elbow. The velocity profiles in surveys A and D at station 3 (figs. 5(a) and (d)) are somewhat different in spite of the fact that they were taken at positions symmetrically located about the center line of the elbow. This difference between the two sides of the elbow may be traced to the nonsymmetrical arrangement of the carburetor components.

Comparison of the velocity distributions obtained at the outlets of the vaned and the vaneless elbows definitely shows that the distortion at the outlet of the vaneless elbow was much less than that at the outlet of the vaned elbow. In addition to decreasing the distortion produced by the throttle, the removal of the turning vanes in the elbow eliminated the distortion caused by the wakes behind the vanes. As a result, it was found that even at wide-open throttle, where the distortion due to the throttle is a minimum, the velocity distribution obtained from the vaneless elbow was better than that obtained from the vaned elbow. Thus, the use of even aerodynamically perfect vanes seems inadvisable immediately downstream from the carburetor when a single butterfly-type throttle is used if a good velocity distribution is desired at the supercharger inlet.

A good velocity distribution at the supercharger inlet is desirable from two considerations. Although the exact effect of the velocity distribution on the fuel and the charge-air distribution among the cylinders of a radial engine is not definitely known, the symmetry of the supercharger impeller and diffuser necessitates a uniform distribution at the impeller inlet in order to insure a uniform distribution in the supercharger-collector outlets. The velocity distribution at the impeller inlet may also have an adverse effect on the supercharger efficiency. Unpublished results of investigations show that a distorted velocity profile at the supercharger inlet may cause a loss in supercharger efficiency as high as 5 percent. This effect would be especially critical at wide-open throttle where a maximum manifold pressure is desired.

From the surveys to determine the effect of vanes on the static-pressure drop through the carburetor and elbow, it was found that the vanes caused a 5-percent increase in pressure drop over that encountered with a vaneless elbow. This difference, however, is not great enough to have any appreciable effect on the manifold pressure.

SUMMARY OF RESULTS

From tests to determine the flow characteristics of a vaned and vaneless supercharger inlet elbow, the following results were obtained. These results apply only to setups in which a carburetor with a single butterfly-type throttle is used.

1. The velocity profile obtained at the outlet of the vaneless elbow was better than that with the vaned elbow at all throttle settings.

2. As the throttle was closed, the relative velocity near the inside surface of the vaned-elbow outlet increased continuously, whereas that at the outside decreased. An additional distortion due to wakes behind the vanes existed at all throttle settings.

3. The peak in the velocity profile produced by the throttle near the inside surface of the outlet of the vaneless elbow was not so pronounced as that of the vaned elbow. This distortion increased as the throttle was closed until a maximum was reached at a throttle setting of approximately 35°. As the throttle was closed beyond this point, the distortion decreased.

4. The static-pressure drop through the carburetor and vaneless elbow was approximately 5 percent less than that through the carburetor and the vaned elbow.

CONCLUSIONS

When a single butterfly-type throttle is used the carburetor throttle angle has a considerable effect on the velocity distribution at the outlet of either a vaned or a vaneless supercharger inlet elbow.

The use of vanes in a supercharger inlet elbow immediately downstream from a carburetor prevents any thorough mixing of the flow, thus causing the distortion produced by the carburetor throttle to be retained through the elbow.

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REFERENCE

1. Moses, Jason J.: Effect of Various Carburetor Throttle Settings on the Flow Characteristics at the Outlet of a Supercharger Inlet Elbow. NACA ARR No. E5E19a, 1945.

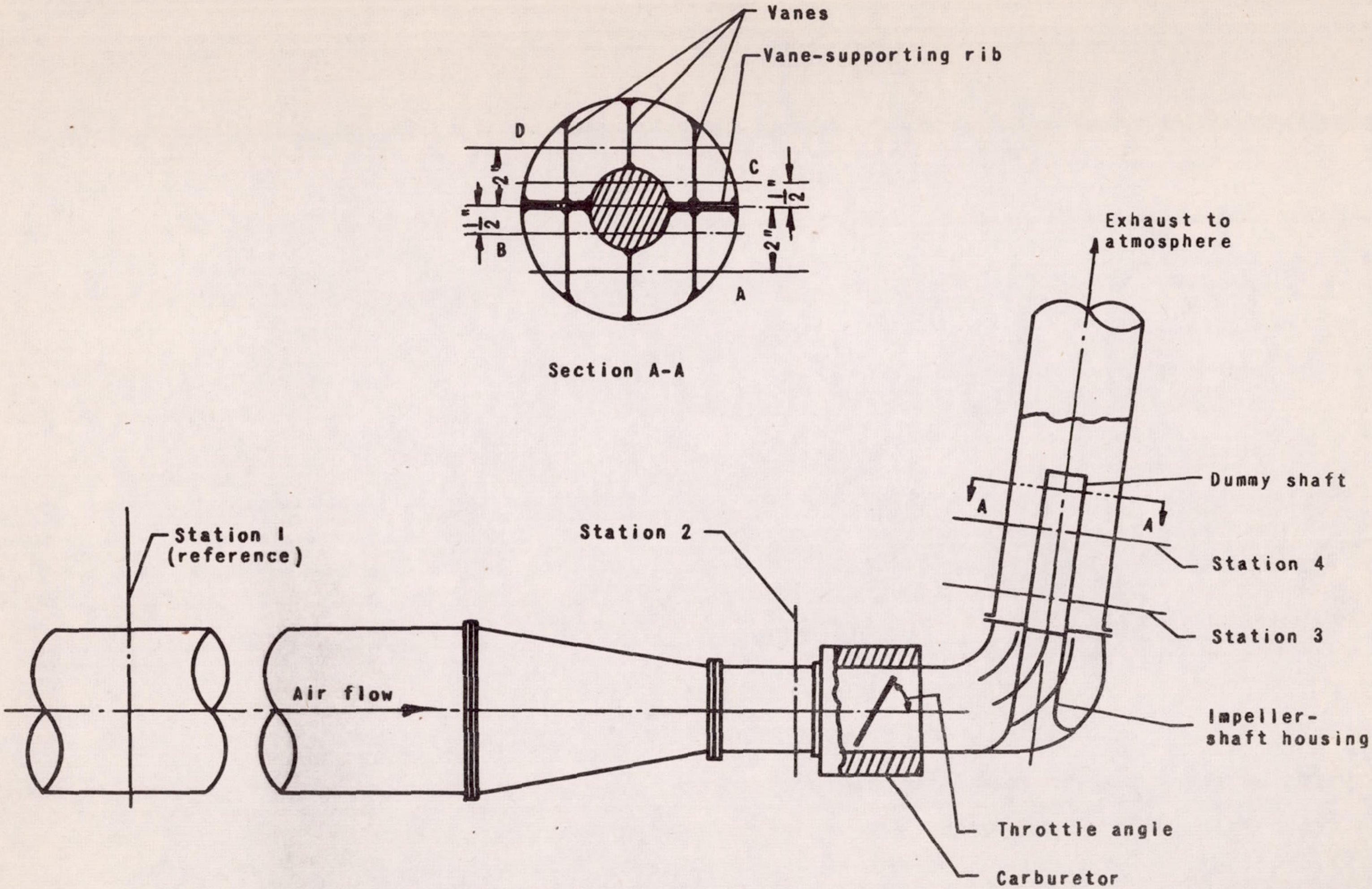

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Figure 1. - Schematic diagram of carburetor and inlet elbow.

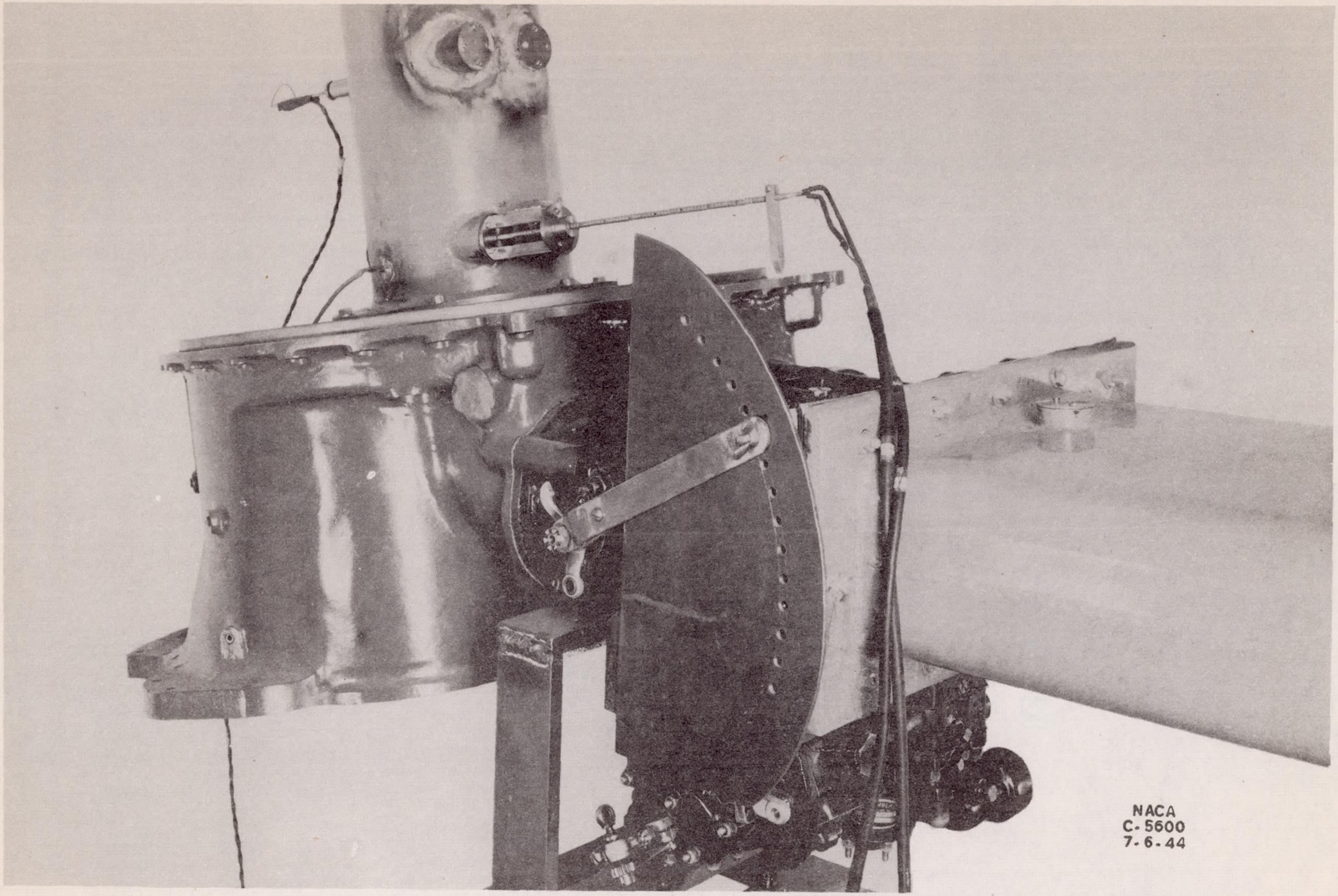


Figure 2. - Installation of carburetor-elbow assembly in duct-component test rig.

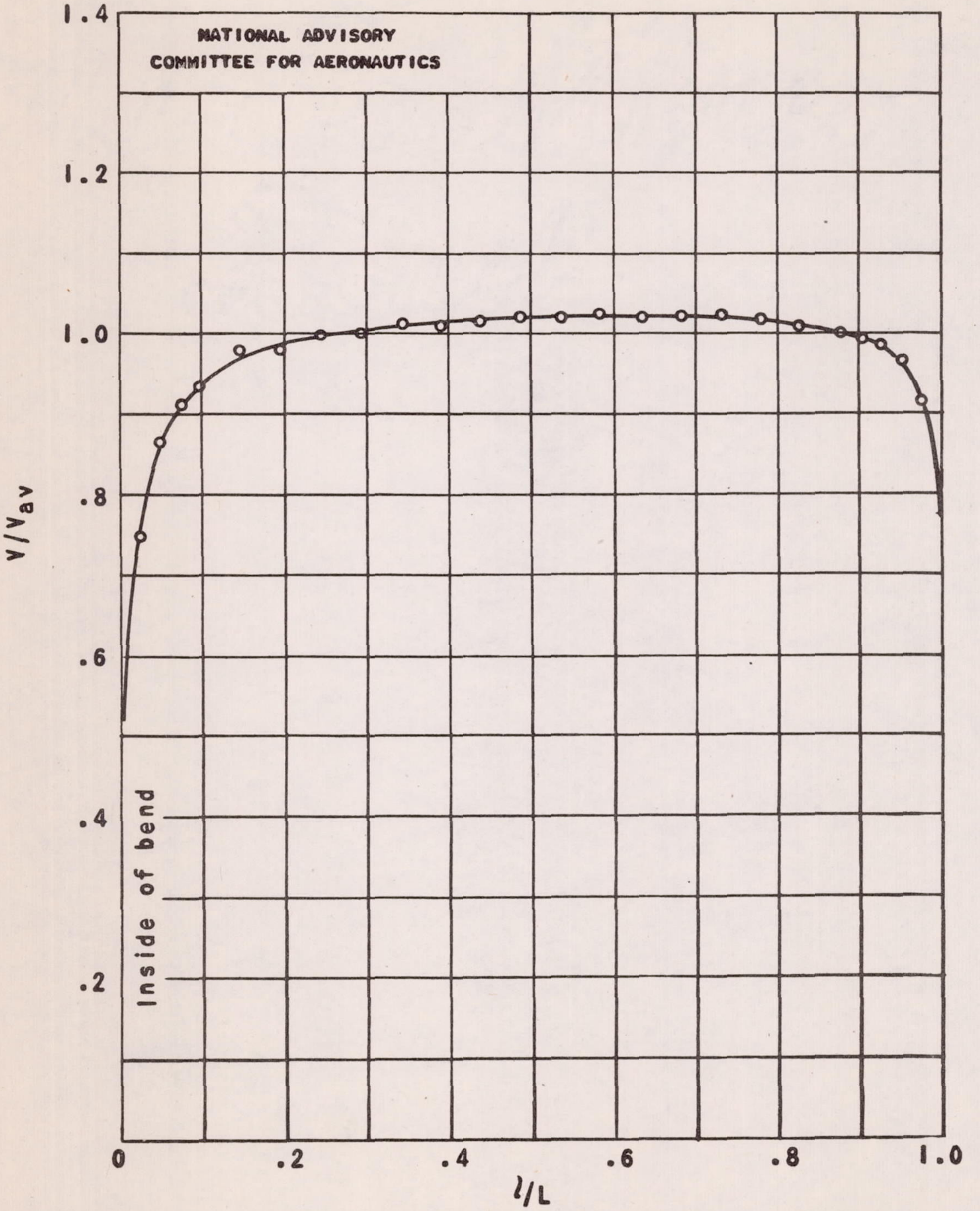
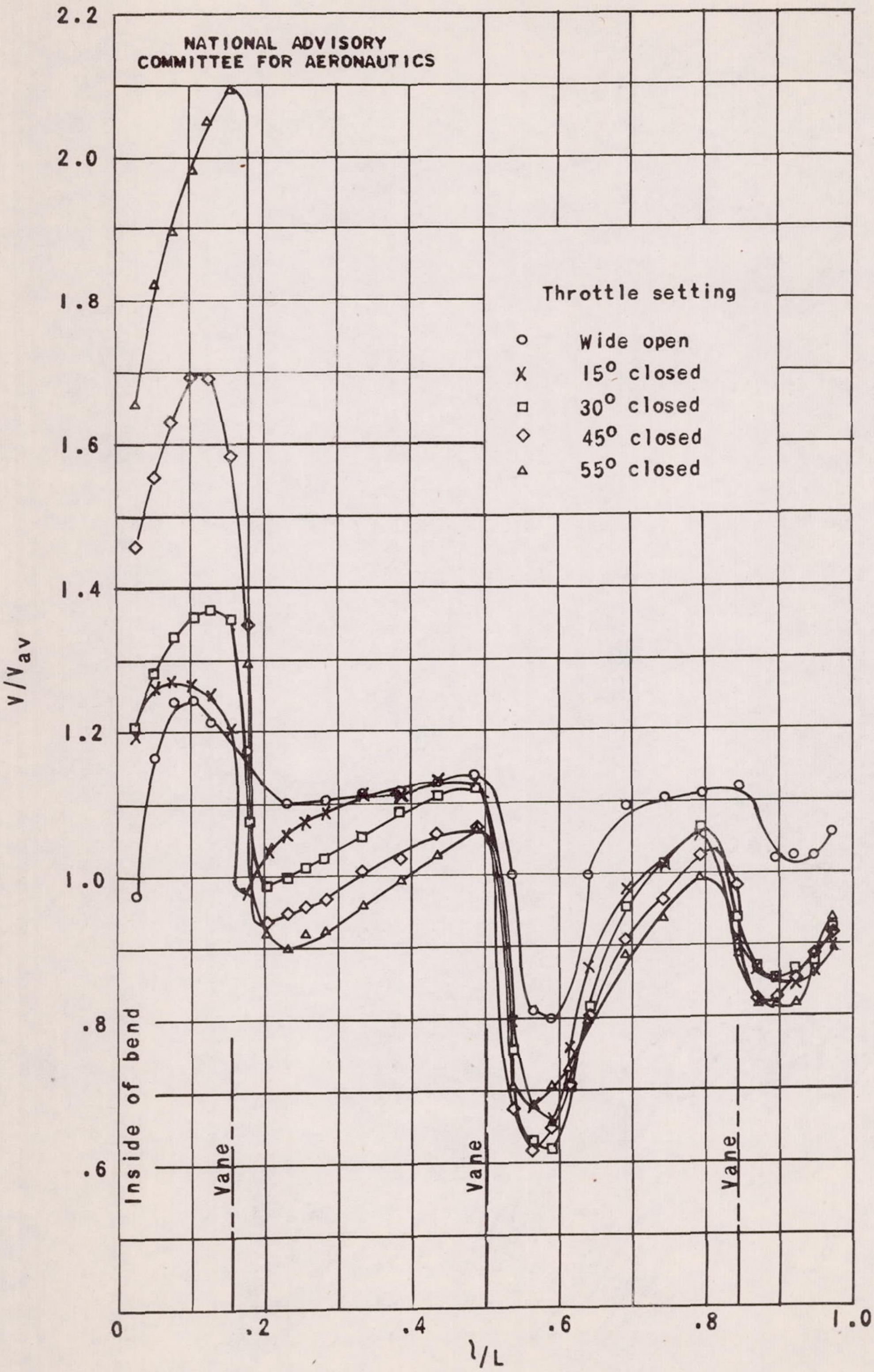
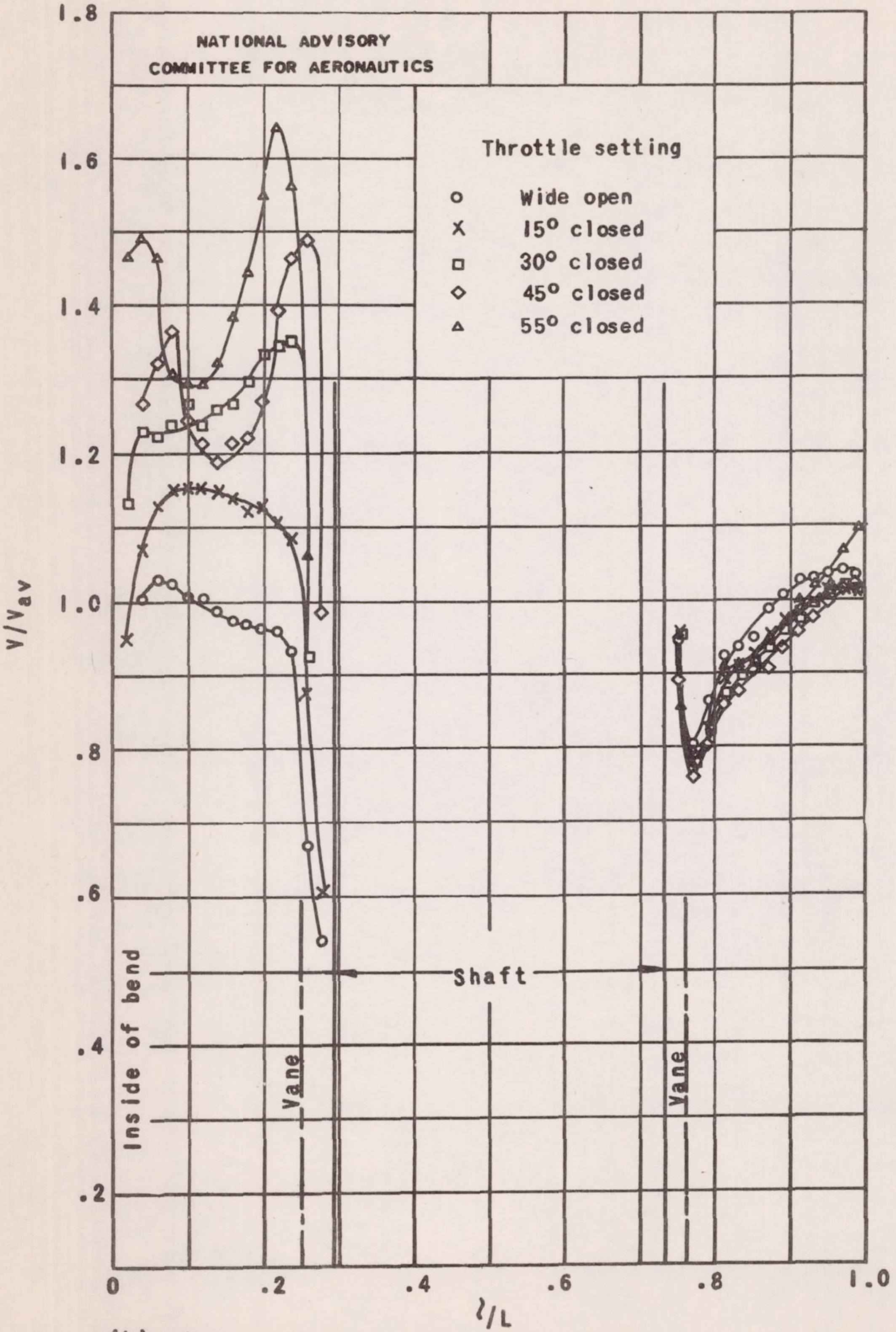


Figure 3. - Velocity profile at carburetor inlet. Station 2; wide-open throttle.

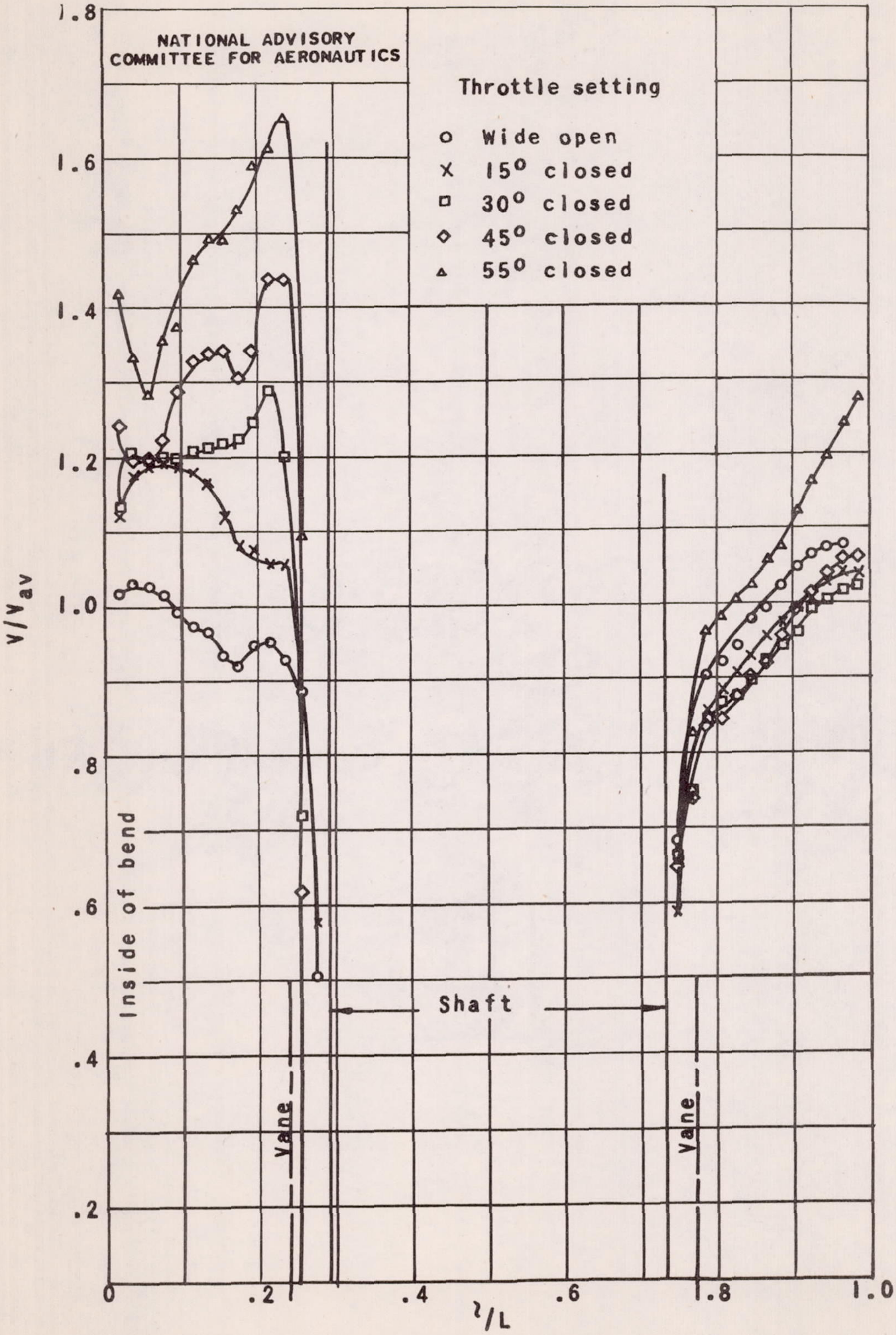


(a) Survey A.

Figure 4. - Effect of throttle angle on velocity profile at vaned-elbow outlet, station 3.

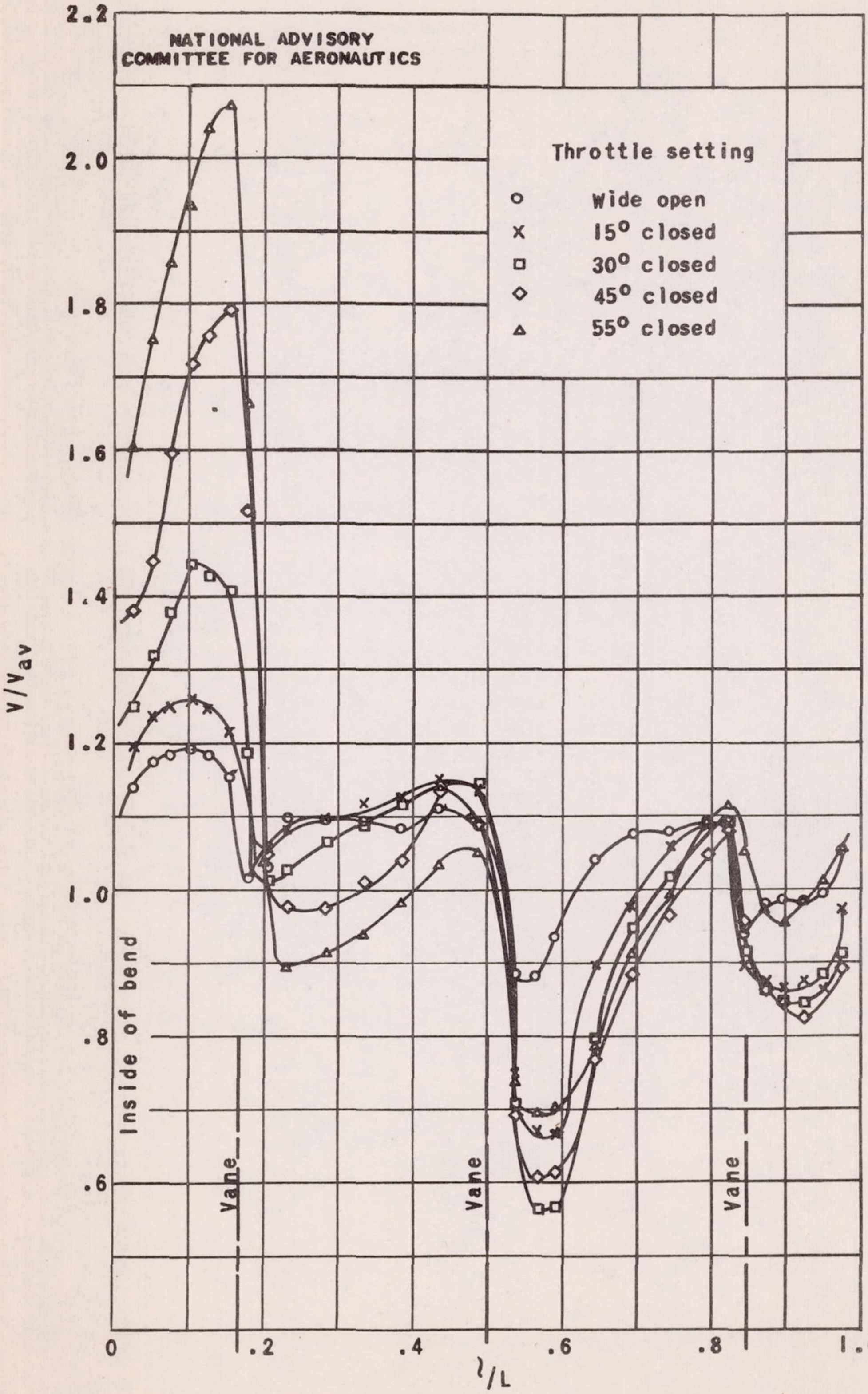


(b) Survey B.
Figure 4. - Continued.



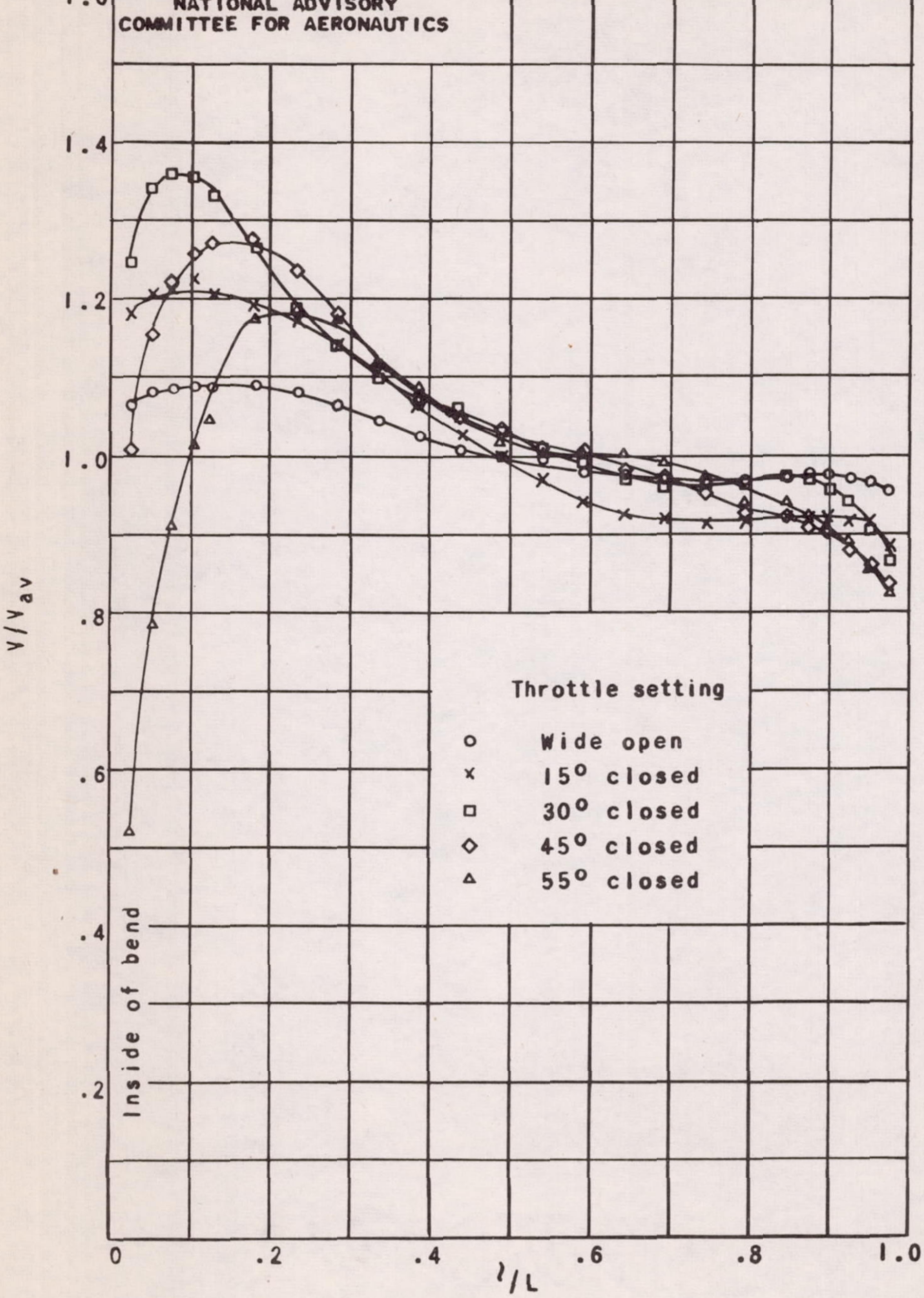
(c) Survey C.

Figure 4. - Continued.



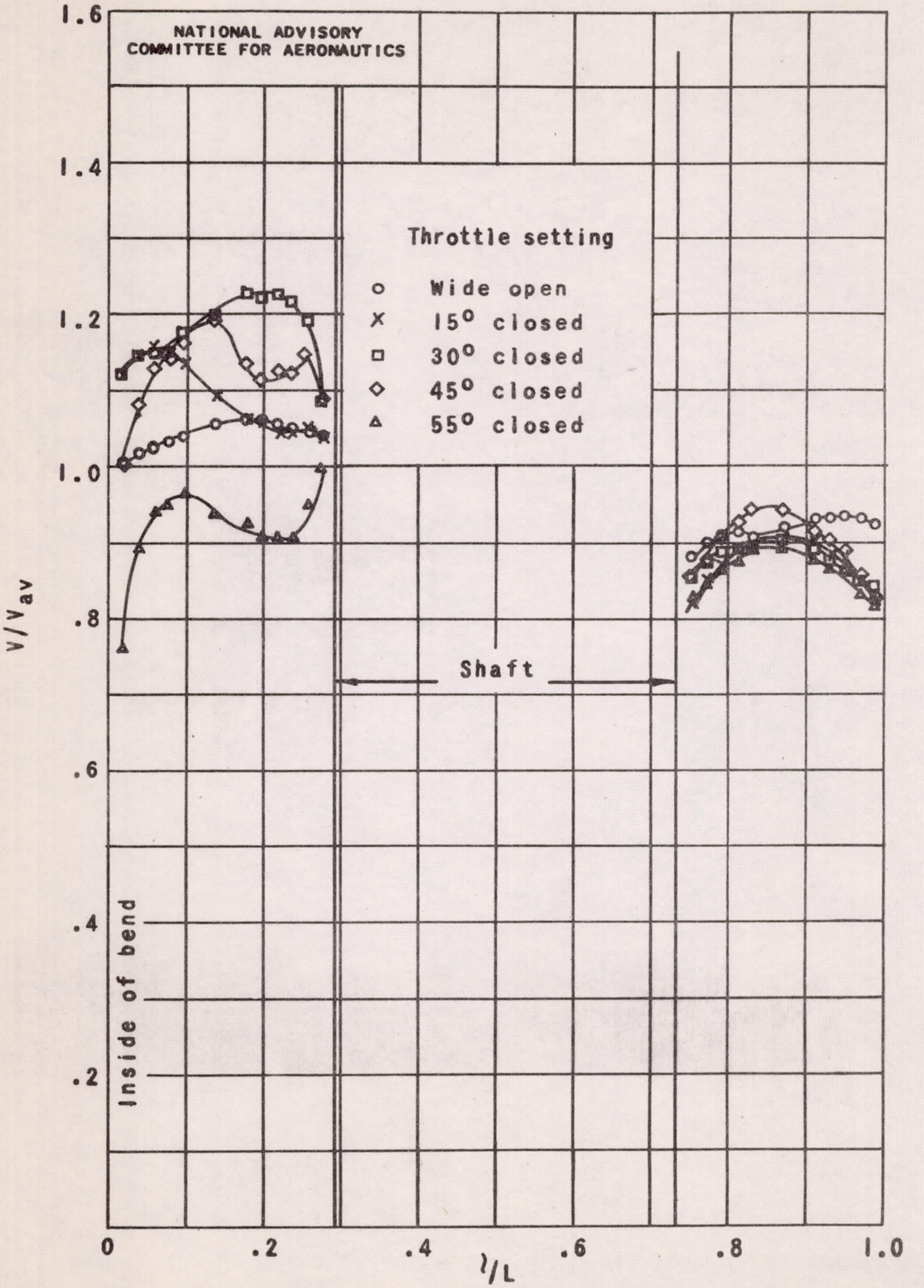
(d) Survey D.

Figure 4. - Concluded.



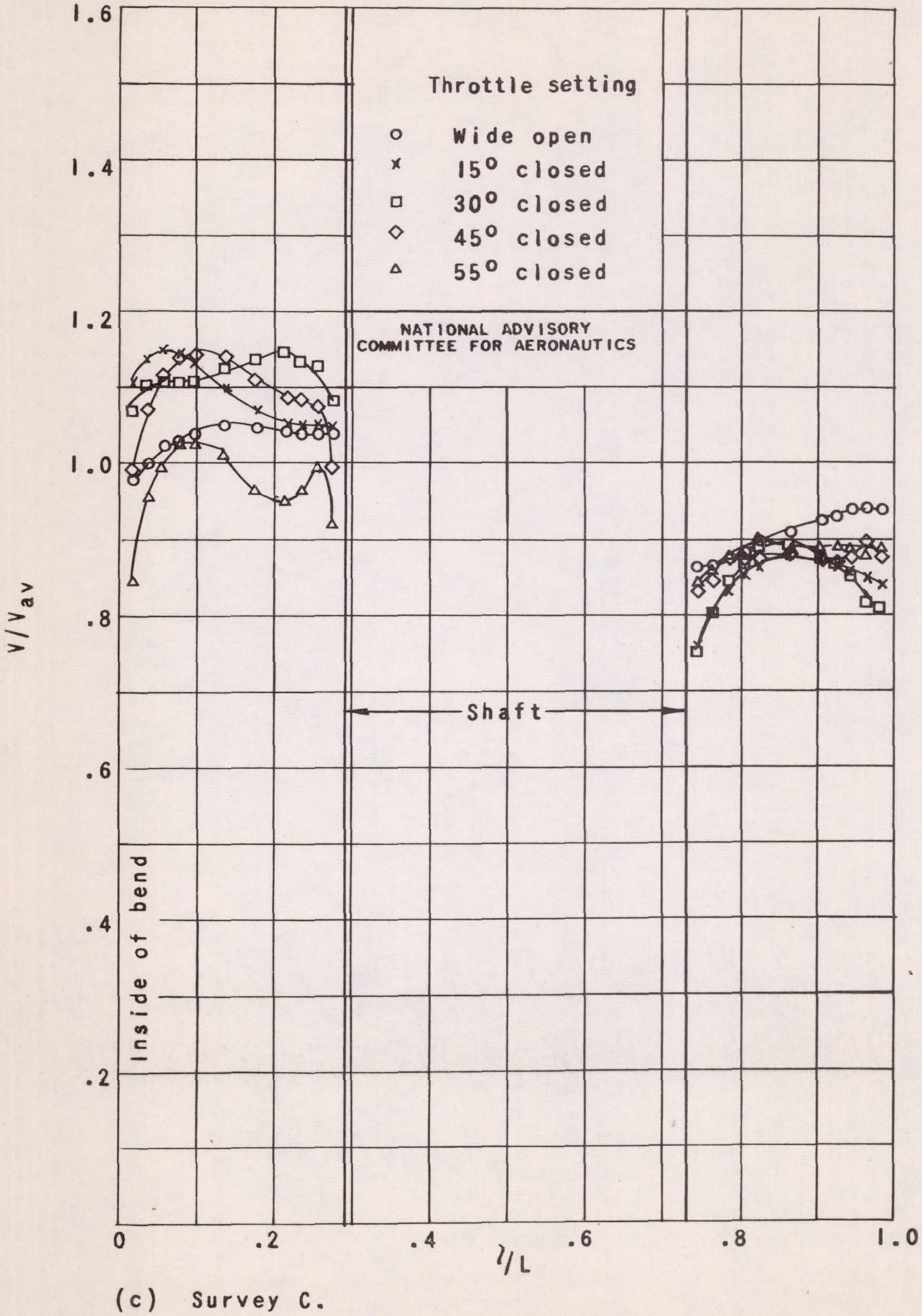
(a) Survey A.

Figure 5. - Effect of throttle angle on velocity profile at vaneless-elbow outlet, station 3.



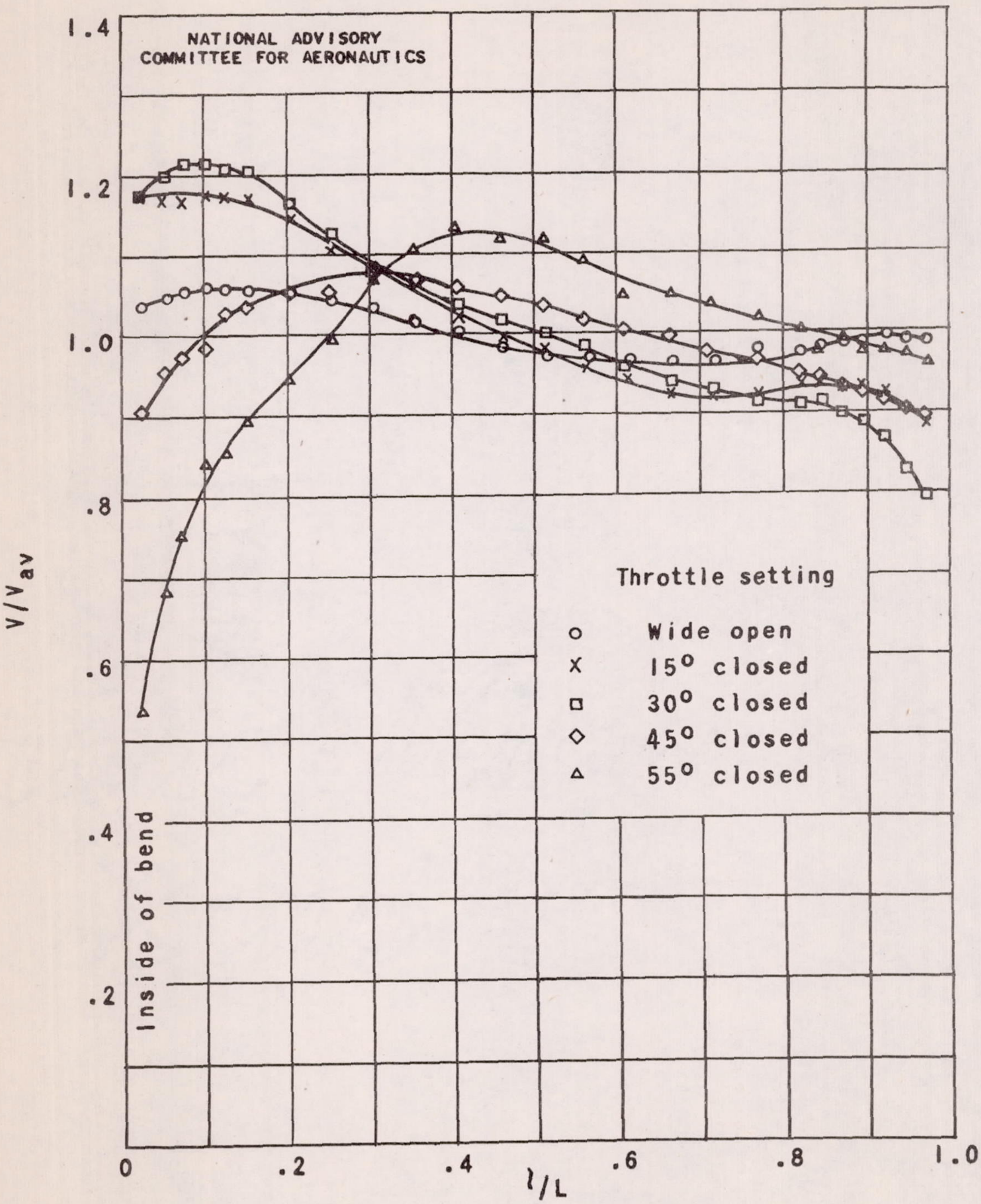
(b) Survey B.

Figure 5. - Continued.



(c) Survey C.

Figure 5. - Continued.



(d) Survey D.

Figure 5. - Concluded.